0882 prescribed burning

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TITLE: SMOKE AND PRESCRIBED BURNING

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In recent years prescribed fire has become an important tool in modern forestry and wildlife habitat management. Its usefulness in preparation of sites, reduction of fire hazards, removal of undesirable species and management of range, wildlife and water is well documented. The ubiquitous smoke from forest wildfires and prescribed burns has long been noted and generally considered a nuisance, but it is only in the last few years that smoke from prescribed burning has been considered and studied as a possible source of air pollution.

Smoke, a mixture of particles, vapors and water droplets can vary widely in composition, quantity, appearance and behavior, even if the fuels are all products of forest and field. The characteristics of the fuels, the process of combustion, the products of combustion and natural decomposition, the type of fire, the kinds of smoke produced and the effectiveness of the management of smoke must be considered in prescribing fire. These factors must be examined in planning for smoke and they may well modify the overall plan for prescribed burning.

Most particles produced in prescribed fires do not remain suspended for long periods. Their lifetime in the air however, ranges from a few seconds to several months. Large particles or small particles that condense to form larger ones settle out of air currents by gravity; their suspended lifetime is no more than a few hours. Particles less than one micron, i.e. those particles too small to settle by gravity, remain aloft and mix with the ambient air. They may serve as condensation nuclei for the steam rising from the burning fuel or for water droplets in a moist air mass. Some small particles may be absorbed onto water droplets. Precipitation is the chief means of removing small particles from the atmosphere. Some particles may not be returned to the ground but may be carried to the high levels of the atmosphere. The effects of increasing the particulate load high in the atmosphere and the contribution of prescribed burning to this load are not known (Roberts 1976).

In an effort to measure particulates from old field fires the New York Unit in cooperation with DEC's Division of Air Resources established a high volume air sampler in the Southern Tier region to monitor weekly changes in air particulates and examine certain effects of prescribed burning. Additional high volume samplers run on the dates of prescribed burns in this area revealed only marginal increases in amount of particulates

over the standard 24 hour sampling period. Only those particulate samples obtained directly from the central smoke plume and extrapolated to a 24 hour period showed a particulate level that exceeded the maximum allowable for New York State. Other samples obtained from 1973 through 1976 at varying distances from prescribed burns showed extrapolated particulate levels well below the allowable state standards. There are indeed a multitude of errors and assumptions that accompany the gathering and interpretation of these data and we are aware of this difficulty. Nevertheless, we have uncovered nothing in this effort that would recommend against the use of prescribed burning as it has been conducted in Region 7 of New York State.

PRESCRIBED FIRE VS. OTHER FIRES

To assess the effects of smoke from prescribed fire on air quality, it is valuable to compare that smoke with smoke from other types of fires. The major categories of smoke that affect both the quality of the air and opinion of the public about pollution are smoke from urban sources, both industrial and non-industrial, and smoke from forest wildfires.

Fuels for these fires vary widely, of course, with most urban fires consuming coal, oil, natural gas, and gasoline. Residential fires consume wood, silk, wool, and plastics. Forest wildfires burn basically the same fuels as prescribed fires but consume three times the amount of fuel per acre (Cooper 1976).

Smoke from nonresidential urban and industrial sources is usually analyzed for carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons and particulates. It is difficult to compare amounts of each kind of emission from various sources because many methods of analyzing, categorizing, labeling and recording have been used. Particulates may include not only unburned carbon and hydrocarbons but also lead, mercury, asbestos, coal and quartz dust, cadmium, DDT, nitrogen, sulfuric acid and various man-made compounds. Table 1 summarizes information from several studies of pollutant emissions. Of the sources of pollutants listed, the internal combustion engine produces the greatest amounts of nitrogen oxides, hydrocarbons and carbon monoxide per ton of fuel. The greatest emission of sulfur dioxide comes from heat generation sources. A total of 25.5 million tons of particulates are produced each year by industrial processes (13.6 tons), fuel combustion in stationary sources (6.7 tons), agricultural and forestry burning (3.2 tons), solid waste disposal (1.1 ton) and transportation (0.9 ton) (Jones 1976).

Forest wildfires often burn large amounts of fuel of a large size and a high moisture content. Thus they burn less efficiently than prescribed fires. The greatest differences between forest wildfires and prescribed fires are the amount of particulates released and the amount of smoke produced; these can be ten times as high for wildfires as for prescribed fires (Cooper 1976). In addition, because wildfires burn explosively at higher temperatures, nitrogen oxide is formed, which is not a product of prescribed fires.

TABLE 1. Pollutant Emission Summary

Source	Emmission pounds per ton of fuel				
	Carbon monoxide	Hydro-carbons	Parti-culates	Nitrogen oxides	Sulfur dioxide
Prescribed fire (agricultural and forest fuels)	40*-161†	2-30§	--	negligible	negligible
Gasoline engine	850*-1080×	130*	4× (excl. hydrocarbons)	40×	--
Heat generation (coal, oil and natural gas fuel)	0.1-140+	0.1-21+	0.3-61+	1.3-17+	0-146+

* Darley et al. 1966 in Komarek 1970

† Southeastern Forest Experiment Station report for New York Cooperative Wildlife Research Unit

§ Darley et al. 1966 in Smith and Suggs 1976

× Feldstein et al. 1963 in Smith and Suggs 1976

\+ Hangerbrauk 1964 in Smith and Suggs 1976

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Although the amounts of particulates in smoke from prescribed fires and smoke from urban sources may be comparable, usually prescribed fires produce fewer emissions and produce fewer and less harmful kinds of emissions.

MANAGEMENT OF SMOKE

The atmosphere has self-cleaning mechanisms that rid the air of foreign substances. Given enough time, even urban air is cleaned. Soil organisms are a natural sink for carbon monoxide (Hall 1972). Natural sinks for other hydrocarbons as well as particulates also exist. Komarek (1973) suggests that carbon particulates, including those from forest fires, are part of the atmosphere's cleaning processes. Pollution occurs only when these processes are overloaded.

Thus the aim of management of smoke from prescribed fires should be to reduce the short-term polluting effects of smoke. The primary goal is to disperse smoke as rapidly as possible, so that there is little or no reduction in visibility for ground or air traffic and so that areas already sensitive to smoke pollution are avoided. The following management recommendations are based primarily on work by Cooper (1976), King et al. (1972), Murphy (1972), Roberts (1976), Schaefer (1976), Tangren (1976) and our own experience with smoke from prescribed burning.

1) Encourage maximum utilization of wood during timber harvest to reduce some of the need for prescribed burning.

2) Define and avoid smoke-sensitive areas such as heavily populated areas, areas with heavy recreation use, hospitals, airports, and highways. Although a smoke column in a constant 15-30 knot wind spreads to a fan with an angle of only 12° at the source, shifting wind directions or speeds can widen this fan considerably. To estimate the maximum area the smoke will affect, one can draw a line representing 60 miles along the horizontal direction the smoke will travel in a steady wind. On each side of this line a line is drawn forming a 30° angle with the center-line. Targets within this triangle are then identified. Numerical models predicting the transport, concentration and dispersal of smoke are presented by Fosberg (1976) and Roberts (1976).

3) Burn during weather conditions which maximize dispersal not accumulation of smoke. Look for steady winds greater than eight knots. Look for wind directions that will carry smoke away from sensitive areas. Look for moderately unstable weather conditions: highly unstable weather is conducive to uncontrolled fire and highly stable conditions result in incomplete combustion. Burn when the mixing height (available from the National Weather Service) is greater than 200 feet to insure vertical dispersal. Take maximum advantage of midday convective heating to disperse smoke. Avoid night burning: the atmosphere becomes more stable at night and smoke settles in low areas and downslope due to surface cooling.

4) Burn when fuels are as dry as possible for efficient, rapid fires. A fire in dry fuel will reach higher temperatures and will disperse the hot smoke higher into the air. In cleared areas burning dry slash with hot intense fires will create high smoke plumes which are rapidly dispersed by strong upper atmosphere winds.

5) Use back fires rather than flank fires or head fires whenever possible. Back fires spread slowly, have good fuel consumption and produce little smoke. Flank and head fires burn rapidly, have poor fuel consumption and produce heavy smoke. Back fires are considerably cleaner than head fires especially in fuels with high moisture content. Back fires in rice straw produced 23 pounds of particulates per ton of fuel with 25 percent or more moisture. Head fires produced 40 pounds of particulates at 25 percent moisture but rose to 70 pounds of particulates per ton of fuel with 67 percent moisture (Darley et al. 1976).

6) Burn to produce particles either so small they create invisible or blue smoke or so large they quickly fall out of the air. Cool, moist fires produce large particulates. Residual particulate loads in the atmosphere can be reduced by burning into moist air that will soon join an actively condensing and precipitating weather system. Burning into dry air, however, evaporates water from the smoke plume and makes smoke less visible. Thus local conditions will determine which kind of particle should be produced. When fuel loads are high, it is probably best to burn rapidly and efficiently with a hot fire and dry air. The smoke produced will be bluish and the particles will eventually be settled by precipitation. When fuel loads are low, cool fires and large particles may be best.

7) Burn only the amount that can be completed in one day. Clean up smoldering logs and stumps. This assures that smoke will disperse before stable night air settles.

CONCLUSIONS

The primary hazard of smoke from prescribed fires is the reduction of visibility in localized areas near the fire. However, effective use of smoke management can reduce this hazard by minimizing the production of smoke that interferes with visibility and by maximizing the rapid dispersal of smoke.

The products of prescribed fires are nonpolluting. They occur in much smaller quantities than products of forest wildfires and urban fires. Their concentrations are not harmful like those of residential and other urban fires. Most of the products of prescribed fires do not remain in the atmosphere for appreciable time because they are removed by the atmosphere's self-cleaning processes. The products of prescribed fires are basically like those products produced by living and decomposing vegetation. In fact, emissions from living and decomposing vegetation are produced in far greater quantities than emissions from prescribed fires.

Although the amount, composition and dispersal of smoke from prescribed fires varies with local conditions of fuel and weather, our conclusions about the relation between this smoke and air pollution all point to the observation that smoke from prescribed fires is neither as hazardous nor as polluting as it once was thought to be. Clearly, there is no information about smoke at present that would recommend against the use of prescribed fire in situations where prescribed burning is feasible and otherwise desirable.

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